Protective Measures Evaluation Summary
Residential Land Use Scenario

Protective Measure Category/Protective Measure Example	Description	Human Health Effectiveness (1) (across categories/within category)	Ecological Effectiveness (1) (across categories/within category)	Cost/Affordability (2)	Practicality (3)
		Consultant Team Suggested Rankings			
Education Programs	Education programs refer to a wide range of broad-based, community-wide efforts to inform individuals and businesses of the presence of contamination and changes in behavior that can be taken to limit or reduce exposure to the contamination.				
Brochures/Fact Sheets/ Newsletters/Videos/Recordings	Used to disseminate information on the presence of contamination, the status and progress of cleanup efforts, and steps that can be taken to limit or reduce exposure to the contamination	EE/1	E/E	$$	PPP
Public Meetings	Used to disseminate information on the presence of contamination, the status and progress of cleanup efforts, and steps that can be taken to limit or reduce exposure to the contamination	EE/2	E/E	$$	PPP
Land Use/Institutional Controls	Actions by government or agreements between two or more parties to limit or prohibit activities that could result in exposure to contaminants or harm a physical barrier or other engineered control. Also includes actions to increase knowledge of contamination, such as disclosure approaches. Often implemented in conjunction with other protective measures, such as physical barriers.				
Permits and Licenses	Can be required for variety of activities from any level of government (local, state, federal).	EE/1	E/E	$	PPP
Zoning	Enacted and enforced by local governments in accordance with state statutes.	EE/2	E/E	$	PPP
Covenants and Easements (often called Deed Restrictions)	Proprietary controls. Covenants usually apply to a single parcel of land. Easements may cover a wide variety of activities or use limitations.	E/3	E/E	$	P
Deed Notices	Informational devices. Deed notices may or may not be enforceable, depending on local or state laws. Applied to individual parcels of land.	E/4	E/E	$$	PP
Residential Real Estate Disclosure Forms and Practices	Information provided to potential purchasers as part of residential real estate transactions (e.g. area-wide environmental disclosure)	E/5	E/E	$	P
Public Health Programs	These programs generally involve activities designed to identify and focus protective measures on specific populations within a community considered to be at high risk and typically include some combination of (1) health monitoring activities (2) one-on-one educational activities and (3) case management or intervention activities.				
Home Visits/One-On-One Education	Trained professionals perform routine visits at high risk residences to evaluate and address sources contributing to elevated exposures and to provide individual instruction on measures to reduce exposure.	EEE/1	E/E	$$	PP
Health Monitoring	Health monitoring includes measuring blood lead levels in children and arsenic levels in hair and urine.	EE/2	E/E	$$	PP
Intervention Activities	Responses to a finding of elevated blood lead levels or urinary arsenic levels may include 1) referral to physician, 2) source investigations and/or implementation of appropriate intervention activities	(4)	(4)	(4)	(4)
Best Management Practices	Best management practices (BMPs) are simple day-to-day activities that property and business owners can follow to limit or reduce exposure to soil contaminants in certain circumstances. Best management practices (BMPs) could involve implementation of actions suggested through educational programs or other actions.				
Damp-mop and Dust or Vacuum with a HEPA Vacuum	Damp-mop and dust floors and counters frequently. Vacuum floors and upholstery frequently using a vacuum with a HEPA filter.	EE/1	E/E	$$	PP
Wash Garden Vegetables and Fruits	Wash garden vegetables and fruits carefully to remove all soil particles.	E/2	E/E	$	PPPP
Practice Personal Hygiene	Wash hands and face thoroughly after working or playing in the soil, especially before eating. No eating or smoking while doing tasks on location.	E/2	E/E	$	PPP
Moisten Soil to Minimize Dust	Wet down soil while gardening or digging to limit the amount of dust inhaled.	E/2	E/E	$	PPPP
Remove Shoes Before Entering Home	Remove work and play shoes before going inside after working or playing in or walking on contaminated soil.	E/3	E/E	$	PPP
Wear Protective Clothing	Wear coveralls and hat while working in contaminated soil. Remove work clothes at completion of task and launder items separately.	E/3	E/E	$	PPPP
Request Soil Test Results	Request and obtain soil test results from oversight agency to learn about contamination levels at nearby properties.	E/4	E/E	$	PPPP

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Residential Land Use Scenario

Protective Measure Category/Protective Measure Example	Description	Human Health Effectiveness (1) (across categories/within category)	Ecological Effectiveness (1) (across categories/within category)	Cost/Affordability (2)	Practicality (3)
		Consultant Team Suggested Rankings			
Physical Barriers	Physical barriers prevent or limit unauthorized access to property or exposure to contaminated soil.				
Pavement Cover	Place concrete pavers or an asphalt pavement cover over exposed soil to reduce exposure to arsenic and/or lead in the soil.	EEE/1	EEE/EEE	$$$$	P
Clean Soil Cover	Place a geotextile fabric directly on top of exposed soil followed by 6 inches of clean fill. Establish and maintain a vegetated surface on top of fill.	EEE/2	EE/EEE	$$$$	PP
Wood Chip Cover	Place a geotextile fabric directly on top of exposed soil followed by several inches of wood chips to reduce exposure to arsenic and/or lead in the soil.	EEE/3	EE/EEE	$$$	PP
Vegetative Cover	Establish and maintain a vegetated surface on top of exposed soil to reduce exposure to arsenic and/or lead in the soil	EEE/4	E/E	$$$	PPP
Fencing	Construct fencing around perimeter of contaminated area to control access to the property.	EE/5	E/E	$$$$	P
Reducing Contamination	Actions to reduce contamination decrease the concentration of contaminants on a property or remove the contamination from the property.				
Soil Removal and replacement	Excavate soil containing arsenic and/or lead and replace this soil with clean fill. Establish and maintain a vegetated surface on top of fill to minimize erosion of the fill.	EEEE/1	EEEE/EEEE	$$$$	PPP
Soil Blending/Tilling	Mix near-surface soil containing arsenic and/or lead with cleaner soil at depth to reduce the concentration of contaminants in the newly formed surface soil.	EEE/2	EEE/EEE	$$$$	PPP
Phytoremediation	Establish and maintain sufficient plant growth on contaminated soil to promote the uptake of arsenic and lead from soil into aboveground portion of plant. Harvest and dispose of plants and then repeat process until desired concentrations are obtained.	EE/3	EE/EE	$$$$	P

(1) Four effectiveness ratings are shown for each protective measure based on the receptor (human health and ecological) and the comparison group (within same protective measure category or across protective measure categories). Effectiveness for the institutional protective measure categories of Education Programs and Public Health Programs is based on the level of participation these measures attract and the ability of these programs to influence participants to change behaviors or implement recommended actions to reduce exposure to contamination. Effectiveness for the physical protective measure categories of Land Use/Institutional Controls, BMPs, Physical Barriers, and Reducing Contamination is based on the ability of these physical protective measures to reduce exposure to contamination. Effectiveness for human health and ecological ratings across categories and for ecological ratings within a category is based on the following scale:
E=no or minimal effect, EE=some effect, EEE=effective, and EEEE=very effective.

(2) Cost is based on applying the protective measure to the entire population described in the residential scenario (i.e. 4,000 properties, 10,000 residents). A 30-year project life is assumed for protective measures with recurring annual costs (e.g. Education Programs, Public Health Programs). Estimated protective measure costs are ranked on the following scale:
$ = $0 to $200,000; $$ = $200,000 to $2,000,000; $$$ = $2,000,000 to $20,000,000; $$$$ = $20,000,000 to $200,000,000.

(3) Practicality is a measure of the technical and administrative barriers to implementing the measure and is ranked on a scale from P=minimal practicality, PP=some practicality, PPP=practical, and PPPP=very practical relative to other protective measure options.

(4) See summaries on BMPs, physical barriers, and reducing contamination.

Protective Measures Evaluation
Residential Land Use Scenario

PROTECTIVE MEASURE	EXAMPLES	DESCRIPTION	EFFECTIVENESS (1)	HH	Eco	COST		PRACTICALITY	
Education Programs		In this context, education programs refer to broad-based, community-wide efforts to inform individuals and businesses of the presence of contamination and changes in behavior that can be taken to limit or reduce exposure to the contamination. Such programs use a wide range of techniques to distribute information and increase public awareness.	Reliable data on the effectiveness of education programs in changing behaviors that lead to reduced exposure are limited. Education programs can reach a wide audience, however, data from a Utah study showed limited effectiveness. Education programs do not address ecological protection.			Costs for education programs vary according to the size of the population being served, activities included in the programs, and the level of staffing required for them. Costs for education programs at four other sites ranged from $15,000 to $75,000 per year. Requires re-occurring annual cost.		Education programs tend to be highly practical in that there are few technical issues or barriers to implementation and they can be administered by a variety of institutions.	
	Public Meetings	Public meetings can be used to disseminate information on the presence of contamination, the status and progress of cleanup efforts, and steps that can be taken to limit or reduce exposure to the contamination	Attendance and participation at public meetings is high initially but wanes considerably during course of cleanup efforts. Other outreach efforts (e.g. school newsletters) may be more effective when attendance is low. It is unclear how effective public meetings are at changing behaviors that lead to reduced exposure.	EE/2	E/E	Cost of public meetings depends on the frequency of meetings, the level of staffing required, the price of meeting facilities, and the extent of publicity for the meetings. Costs are generally low for agencies or organizations that regularly conduct them and therefore have access to appropriate facilities and staff resources (see above cost range).	$$	Public meetings can be a practical means of conveying information to large groups of people in that there are few technical or administrative barriers to their implementation.	PPP
	Brochures/Fact Sheets/Newsletters/ Videos/Recordings	Brochures/fact sheets/newsletters can be used to disseminate information on the presence of contamination, the status and progress of cleanup efforts, and steps that can be taken to limit or reduce exposure to the contamination	There is little data to suggest that written educational materials alone are effective at changing behavior and reducing actual exposure. Effectiveness of written materials depends on how widely they are distributed and whether people read and retain the information.	EE/1	E/E	Written materials are generally not expensive to develop and maintain. Costs depend on the method of distribution. More passive means of communicating information (e.g. website, school newsletter) are generally cheaper than more active forms of communicating information, such as distributing educational materials in a door-to-door outreach effort (see above cost range).	$$	Written educational materials are highly practical in that there are few technical or administrative barriers to their implementation.	PPP

(1) See footnote 1 to the summary table for a definition of the effectiveness rating. Effectiveness for Education Programs is based on the level of participation the programs attract and the ability of these programs to influence participants to change behavior or implement recommended actions to reduce exposure to contamination. The effectiveness of the various protective measures that these programs recommend (e.g. dust control) is presented under the table for that particular protective measure.

Protective Measures Evaluation
Residential Land Use Scenario

PROTECTIVE MEASURE	EXAMPLES	DESCRIPTION	EFFECTIVENESS (1)	HH	Eco	COST		PRACTICALITY	
Land Use Controls		Actions by government or agreements between two or more parties to limit or prohibit activities that could result in exposure to contaminants or harm a physical barrier or other engineered control. Also includes actions to increase knowledge of contamination, such as disclosure approaches. Often implemented in conjunction with other protective measures, such as physical barriers.	Affected by: enforceability of the control (and by whom); how information about the control is distributed or accessed; and the longevity of the control (e.g., does it run with the land?). Land use controls do not address ecological protection.			Little information currently available about cost of implementation.		Affected by: who administers the control and under what authority; funding source; methods of monitoring.	
	Zoning	Enacted and enforced by local governments in accordance with state statutes.	Variable; affected by requirements under zoning, enforcement, and longevity. Local political pressures for development can make it easier to repeal the restrictions on a given site or make it harder to enforce existing restrictions. Advantages: designated uses run with the land and can be applied to a large number of parcels. Doesn't affect current uses.	EE/2	E/E	Relatively low cost; typically already conducted by local government.	$	Use of zoning by local government is well-established. Affected by level of oversight.	PPP
	Permits and licenses	Can be required for variety of activities from any level of government (local, state, federal).	Enforceable by law. Affected by requirements under permit, enforcement. Don't affect current uses. Typically do not run with the land.	EE/1	E/E	Relatively low cost. Affected by: enforcement and level of oversight; administrative / processing expenses.	$	Commonly implemented at all levels of government. Affected by: types of permits required; level of government involved; and level of oversight.	PPP
	Covenants and easements (often called deed restrictions)	Proprietary controls. Covenants usually apply to a single parcel of land. Easements may cover a wide variety of activities or use limitations.	Unclear. Enforceability usually reserved for the holder of the covenant or easement. Advantages: may be binding on subsequent owners.	E/3	E/E	Relatively low cost. Affected by purpose, parties involved, enforcement, and oversight provided.	$	Affected by: parties involved, purpose, and oversight provided.	P
	Deed notices	Informational devices. Deed notices may or may not be enforceable, depending on local or state laws. Applied to individual parcels of land.	Affected by enforceability, oversight, and availability of information. Typically, for a land transfer, future land owners (or potential owners) rely on county or state systems of deed records to learn about land use restrictions and potential hazards due to soil contamination.	E/4	E/E	Relatively low cost. Use of model language decreases cost to entity placing control. Biennial reporting estimated as $500/property (NJ).	$$	Implementation can be incorporated into existing systems. Affected by level of oversight.	PP
	Residential real estate disclosure forms and practices	Information provided to potential purchasers as part of residential real estate transactions (e.g. area-wide environmental disclosure)	Affected by: information available to property sellers, implementation method. Little effect until time of property transfer.	E/5	E/E	Relatively low cost. Costs borne by property sellers.	$	Increased if can be incorporated into existing disclosure system.	P

(1) See footnote 1 to the summary table for a definition of the effectiveness rating.

Protective Measures Evaluation
Residential Land Use Scenario

PROTECTIVE MEASURE	EXAMPLES	DESCRIPTION	EFFECTIVENESS (1)	HH	Eco	COST		PRACTICALITY	
Public Health Programs		These programs generally involve activities designed to identify and focus protective measures on specific populations within a community considered to be at high risk. These programs generally include some combination of (1) health monitoring activities (2) one-on-one educational activities and (3) case management or intervention activities.	Data on effectiveness is limited. Public health programs do not address ecological protection.			Requires re-occurring annual cost.			
	Health monitoring	Health monitoring includes measuring blood lead levels in children and arsenic levels in hair and urine.	Blood lead screening can be an effective method for identifying exposed individuals if there is a high level of participation in the testing program and testing is performed at times that capture high exposure periods. Methods for monitoring arsenic (urinary arsenic measurements and hair samples) are available. However, a number of implementation and interpretation issues exist that limit the utility of these methods for identifying persons with elevated exposures.	EE/2	E/E	Costs for health monitoring depend primarily on the size of the population served and the type and frequency of monitoring. Little actual cost data available. Estimated health monitoring costs based on cost estimates for the Vasquez Boulevard/Interstate 70 Superfund Site are $50,000 for setup and $100,000-$150,000/yr for ongoing monitoring (approximately 700 samples analyzed per year).	$$	The basic institutional structures needed to implement health monitoring are already in place in Washington through state and local health departments. However, wide scale implementation of health monitoring programs would be constrained by the lack of an adequate and predictable source of funding, equipment, and personnel. In addition, health monitoring/education programs do not appear to work well as an intervention strategy in disadvantaged communities.	PP
	Home visits/one-on-one education	Trained professionals perform routine visits at high risk residences to evaluate and address sources contributing to elevated exposures and to provide individual instruction on measures to reduce exposure.	Available information indicates that education programs involving home visits can be beneficial (in terms of modifying participants behavior to reduce exposure to lead and arsenic) in some situations. Health officials in some areas have reported 15-50% reduction in blood lead levels following education outreach activities. Some of these programs have also been shown to be effective in reducing the proportion of children with blood lead levels above 15-20 ug/dL.	EEE/1	E/E	Costs for home counseling/case management depend on the level of participation and can be very high if the number of residences receiving home visits is large. Limited cost data for home counseling/case management is available.	$$	Home counseling/case management programs tend to be practical in that there are few technical issues or barriers to implementation and they can be administered by a variety of institutions. The practicality of implementing home counseling/case management on a large scale is negatively impacted by the high cost.	PP
	Intervention activities	Responses to a finding of elevated blood lead levels or urinary arsenic levels may include 1) referral to physician, 2) source investigations and/or implementation of appropriate intervention activities	See summaries on BMPs, physical barriers, and reducing contamination			See summaries on BMPs, physical barriers, and reducing contamination		See summaries on BMPs, physical barriers, and reducing contamination	

(1) See footnote 1 to the summary table for a definition of the effectiveness rating. Effectiveness for Public Health Programs is based on the level of participation the programs attract and the ability of these programs to influence participants to change behavior or implement recommended actions to reduce exposure to contamination. The effectiveness of the various protective measures that these programs recommend

Protective Measures Evaluation
Residential Land Use Scenario

PROTECTIVE MEASURE	EXAMPLES	DESCRIPTION	EFFECTIVENESS (1)	HH	Eco	COST		PRACTICALITY	
Best Management Practices		Best management practices (BMPs) are simple day-to-day activities that property and business owners can follow to limit or reduce exposure to soil contaminants in certain circumstances. Best management practices (BMPs) could involve implementation of actions suggested through educational programs or other actions.	Limited data exists on the effectiveness of the individual BMPs listed below in preventing and/or reducing exposure to lead and arsenic because BMPs are typically implemented together with other BMPs or protective measures so the effects of individual BMPs can be difficult to isolate. BMPs do not address ecological protection.			Costs to implement most BMPs are typically low relative to other protective measures			
	Practice personal hygiene	Wash hands and face thoroughly after working or playing in the soil, especially before eating. No eating or smoking while doing tasks on location.	Effective in removing lead and arsenic from surface of skin but unlikely to contribute significantly to overall exposure reduction.	E/2	E/E	$0.00	$	Highly practical for adults, less practical for children	PPP
	Wash garden vegetables and fruits	Wash garden vegetables and fruits carefully to remove all soil particles.	Effective in removing lead and arsenic from surface of fruit and vegetables but unlikely to contribute significantly to overall exposure reduction.	E/2	E/E	$0.00	$	Highly practical	PPPP
	Remove work and play shoes before entering home	Remove work and play shoes before going inside after working or playing in or walking on contaminated soil.	Effective in limiting the entry of lead and arsenic into the home but unlikely to contribute significantly to overall exposure reduction.	E/3	E/E	$0.00	$	Highly practical for adults, less practical for children	PPP
	Damp-mop and dust house or vacuum with HEPA vacuum	Damp-mop and dust floors and counters frequently. Vacuum floors and upholstery frequently using a vacuum with a HEPA filter.	Studies that evaluated the combined effect of home counseling/case management and dust control using HEPA vacuuming and other dust control measures (e.g. damp-mop and dusting) generally report small reductions in blood lead concentrations but relatively high reductions in dust-lead loadings.	EE/1	E/E	Additional cost for supplying HEPA type vacuums. No other additional cost is assumed.	$$	Less practical relative to other BMPs due to the need for residents to conduct frequent cleaning	PP
	Moisten soil to minimize dust while gardening or digging	Wet down soil while gardening or digging to limit the amount of dust inhaled.	Effective at limiting soil inhalation during gardening if soil is thoroughly wetted but unlikely to contribute significantly to overall exposure reduction.	E/2	E/E	$0.00	$	Highly practical	PPPP
	Wear protective clothing	Wear coveralls and hat while working in contaminated soil. Remove work clothes at completion of task and launder items separately.	Effective at limiting the spread of contamination from work site to home but unlikely to contribute significantly to overall exposure reduction.	E/3	E/E	$0.00	$	Highly practical	PPPP
	Request soil test results	Request and obtain soil test results from oversight agency to learn about contamination levels at nearby properties.	Effective at learning whether a potential exposure hazard exists.	E/4	E/E	$0.00	$	Highly practical	PPPP

(1) See footnote 1 to the summary table for a definition of the effectiveness rating.

Protective Measures Evaluation
Residential Land Use Scenario

PROTECTIVE MEASURE	EXAMPLES	DESCRIPTION	EFFECTIVENESS (1)	COST (2)				PRACTICALITY	
				HH	Eco				
Physical Barriers		Physical barriers prevent or limit unauthorized access to property or exposure to contaminated soil.							
	Fences	Construct fencing around perimeter of contaminated area to control access to the property.	Fencing may not effectively prevent access nor does it prevent residents living within fenced area from contacting contaminated soil. Fencing does not prevent generation or transport of air-borne particulates.	EE/5	E/E	$6,000-$12,000/property	$$$$	Fencing can typically be readily installed on most properties. Property owners may resist installation of fencing due to loss of property use or aesthetic impacts on the property or neighborhood.	P
	Vegetative Cover	Establish and maintain a vegetated surface on top of exposed soil to reduce exposure to arsenic and/or lead in the soil	Effectiveness depends on land use, climate, and maintenance. Irrigation may be needed. Not effective during intrusive activities.	EEE/4	E/E	$1,000-$3,000/property	$$$	Vegetative covers can typically be readily installed on most properties. Maintaining cover effectiveness will, in most cases, require long-term maintenance.	PPP
	Wood Chip Cover	Cover exposed soil with a geotextile fabric and several inches of wood chips to reduce exposure to arsenic and/or lead in the soil.	Effectiveness depends on thickness, land use and maintenance. Not effective during intrusive activities. Geotextile fabric may provide some ecological protection.	EEE/3	EE/EEE	$3,000-$6,000/property (includes wood chip replacement every 10 years)	$$$	Wood chip covers can typically be readily installed in appropriate areas on most properties. Aesthetic qualities and appropriate surface uses may limit the use of wood chip covers to small areas. Maintaining cover effectiveness requires periodic replacement of wood chips.	PP
	Clean Soil Cover	Place a geotextile fabric directly on top of exposed soil followed by 6 inches of clean fill. Establish and maintain a vegetated surface on top of fill to minimize erosion of the fill.	Effectiveness depends on thickness, land use, climate, and maintenance. Not effective during intrusive activities. Geotextile fabric may provide some ecological protection.	EEE/2	EE/EEE	$6,000-$12,000/property	$$$$	Clean fill covers can typically be readily installed on most properties, however, some regrading may be needed to accommodate additional fill. Maintaining cover effectiveness will, in most cases, require long-term maintenance	PP
	Pavement Cover	Place concrete pavers or an asphalt pavement cover over exposed soil to reduce exposure to arsenic and/or lead in the soil.	Very effective at preventing direct contact except during intrusive activities.	EEE/1	EEE/EEE	$15,000-$30,000/property (includes asphalt resurfacing every 10 years)	$$$$	The use of paved surfaces as covers is typically limited to driveway and patio areas at residential properties.	P

(1) See footnote 1 to the summary table for a definition of the effectiveness rating.

(2) Based on a 10,000 sq. ft. lot with one-half of the lot containing accessible contaminated soil.

Protective Measures Evaluation
Residential Land Use Scenario

PROTECTIVE MEASURE	EXAMPLES	DESCRIPTION	EFFECTIVENESS (1)	COST (2)				PRACTICALITY	
				HH	Eco				
Reducing Contamination		Actions to reduce contamination decrease the concentration of contaminants on a property or remove the contamination from the property.							
	Soil Blending/Tilling	Mix near-surface soil containing arsenic and/or lead with cleaner soil at depth to reduce the concentration of contaminants in the newly formed surface soil.	Very effective in short term and long term for both human health and ecological receptors if subsurface soil is clean.	EEE/2	EEE/EEE	$7,000-$27,000/property	$$$$	Practicality depends on depth of contaminated layer and presence of obstructions such as utilities and buildings. For shallow contamination with clean subsurface soil, easily implementable away from buildings and utilities.	PPP
	Soil Removal and Replacement	Excavate soil containing arsenic and/or lead and replace this soil with clean fill. Establish and maintain a vegetated surface on top of fill to minimize erosion of the fill.	Very effective in short term and long term for both human health and ecological receptors	EEEE/1	EEEE/EEEE	$11,000-$60,000/property	$$$$	Practicality depends on access, depth of contaminated soil, proximity to disposal location and clean fill source, and presence of utilities and buildings. Easily implementable in areas with good access to mechanical excavating equipment and few site interferences such as utilities, fences, and structures.	PPP
	Phytoremediation	Establish and maintain sufficient plant growth on contaminated soil to promote the uptake of arsenic and lead from the soil into the aboveground portion of the plant. Harvest and dispose of the plants and then repeat process until desired concentrations are obtained.	Effectiveness in reducing concentrations is unknown with little full-scale experience on treatment of lead and arsenic-contaminated soil. Time required for completion dependent on soil concentration and plants selected. Emerging technology.	EE/3	EE/EE	$8,000-$40,000/property	$$$$	Need for long-term (greater than 5 years) planting, harvesting, and disposal greatly reduces practicality. Phytoremediation limits the use of land undergoing treatment. Testing needed to establish proper plants for the contaminant and climate. Little full scale experience. Can be used in areas with limited access.	P

(1) See footnote 1 to the summary table for a definition of the effectiveness rating.

(2) Based on a 10,000 sq. ft. lot with one-half of the lot containing accessible contaminated soil ranging from 0.5 to 1.5 ft. deep.